# Summary of Industry Trends Program Enhancement Effort for the Initiating Events Cornerstone of Safety

# 1 Reasons for Enhancing Current ITP Performance Indicators

Current ITP performance indicators have both strengths and weaknesses. Strengths include availability of historical results, continuity and consistency in yearly evaluations, and broad coverage of the Cornerstones of Safety. However, ITP performance indicator weaknesses in the Initiating Events and Mitigating Systems Cornerstones of Safety include (1) overlapping coverage for certain cornerstones, (2) limited risk coverage, and (3) difficulties in interpreting the risk significance of significant adverse trends that are detected.

In terms of risk coverage, work documented in NUREG-1753, "Risk-Based Performance Indicators: Results of Phase 1 Development," indicates that the ROP indicators "unplanned scrams" and "scrams with loss of normal heat removal" probably cover less than 20 percent of the total internal event core damage risk for the Initiating Events Cornerstone of Safety. (The other 80 percent of risk involves less frequent initiating events that cannot be monitored on a plant-specific basis over the limited, 3-year period covered by the ROP indicators.) This limited coverage of risk by the ROP performance indicators is supplemented by inspections.

Moreover, it can be difficult to determine whether an adverse trend is risk significant if one is detected. This is because not all scrams are equally serious in terms of risk. For example, an adverse trend in "automatic scrams" due to "general transients" might be offset by a favorable (decreasing frequency) trend in "scrams with loss of normal heat removal." The ITP has no established method for determining risk significance of broad categories such as "unplanned scrams," nor a mechanism for aggregating and interpreting offsetting trends at the Cornerstone of Safety level.

As a first step in enhancing the ITP to remedy the weaknesses discussed above, the Initiating Event Cornerstone of Safety was chosen as the area of focus. Work focused on development of performance indicators that did not overlap in coverage, significantly increased the risk coverage, and provided a mechanism for determining the risk significance of changes in performance, at both the individual initiating event level and at the integrated Cornerstone of Safety level. The process and results are documented in the following sections.

#### 2 Enhancement Process for Initiating Events Cornerstone of Safety

To enhance the ITP coverage of the Initiating Events Cornerstone of Safety, a three-step process was used. The first step was to identify appropriate classes of initiating events. Then methods for trending and establishing performance-based prediction limits for these individual event classes were developed (Tier 1, performance-based monitoring of classes of initiating events). Finally, an integrated, risk-informed indicator was developed by combining the individual initiating event class information (Tier 2, risk-informed monitoring at the Cornerstone of Safety level). Figure A2-1 shows the ITP process with respect to the integrated initiating event indicator.

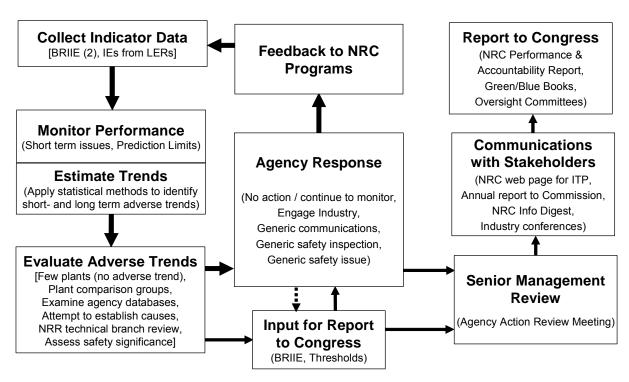


Figure A2-1 BRIIE and the ITP process

#### 2.1 Identification of Risk-Significant Initiating Events

The initiating event study (NUREG/CR-5750, "Rates of Initiating Events at U.S. Nuclear Power Plants") provides data for a large number of initiating event types for calendar year (CY) 1987 through CY 1995. (NRC is continually updating these data, but NUREGs are no longer being published. Instead, the results are posted on an internal NRC Web site with plans to post them on the NRC public Web site.) Initiating event types are defined in that study as unplanned reactor trips that occur while a plant is critical and at or above the point of adding heat. A subset of these events has been identified as being risk significant (NUREG-1753). The list of risk-significant initiating event types considered in the ITP consists of the following 10 initiating events applicable to PWRs and 9 applicable to BWRs:

General Transients

Loss of Heat Sink

Loss of Feedwater

Loss of Offsite Power

Loss of Vital AC Bus

Stuck-Open SRV

Loss of Instrument Air

Small/Very Small LOCA

Steam Generator Tube Rupture (PWR only)

In general, these risk-significant initiating event types cover approximately 90% of the internal event core damage risk (excluding internal flooding) from the 103 operating commercial nuclear power plants in the U.S. Also, these initiating events do not overlap.

#### 2.2 Performance Monitoring of Risk-Significant Initiating Event Classes (Tier 1)

The proposed Tier 1 activity involves trending risk-significant initiating events and monitoring yearly industry performance against prediction limits. To accomplish this, up-to-date baseline frequencies were established for each of the risk-significant initiating events. Then, given these baseline frequencies and estimated yearly industry total critical reactor years of operation, the ITP enhancement determined performance-based prediction limits. Data for these initiating events (numbers of event occurrences and corresponding reactor critical years) are already being collected and analyzed by the NRC on a continual basis, so no additional data collection is needed to support the Tier 1 activities.

The prediction limits are statistically determined and performance based. Both 95% and 99% limits have been estimated for illustrative purposes. An expert elicitation approach is proposed to select the appropriate limits for the Tier 1 activity.

As an example of the Tier 1 trending analysis, the historical performance of the PWR general transients is shown in Figure A2-2. Over the period FY 1988 through approximately FY 1997, industry performance improved considerably (the initiating event frequency dropped). However, over the period FY 1998 through FY 2001 (the period used for determining an up-to-date baseline frequency), the industry performance was essentially constant. Including the FY 2002 initiating event data in the Tier 1 trending analysis did not produce any increasing trends.

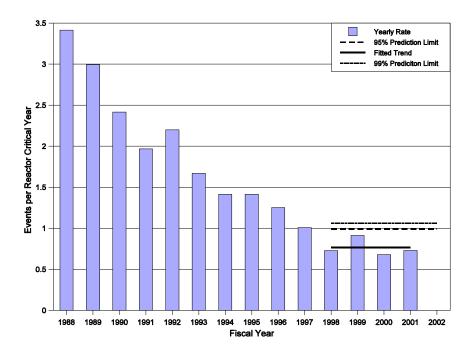


Figure A2-2 Estimated annual frequency of PWR general transient initiating event. The trend over the baseline period is not statistically significant (p-value = 0.625).

These ITP Tier 1 activities will help the NRC identify degrading industry performance as an adjunct to the plant-specific performance assessment performed as part of the ROP. Potential NRC responses if one or more of the prediction limits are reached or exceeded are outlined in Section 4 of this attachment. Also, example scenarios are presented in Section 4 for illustrative purposes. Tier 1 activities and results are not reported to the U.S. Congress, but they are used by the NRC as a diagnostic tool. The Tier 1 results will be placed on the NRC Web site for access by interested stakeholders. Therefore, the proposed Tier 1, performance-based monitoring of risk-significant initiating event types supports many uses of ITP results discussed in the main body of this paper.

## 2.3 Risk-Informed Monitoring of Initiating Events Cornerstone of Safety (Tier 2)

An integrated performance indicator is proposed for ITP Tier 2 coverage of the Initiating Events Cornerstone of Safety. It involves evaluating the risk significance of changes in industry initiating event class performance (the results of the Tier 1 activity). Risk significance is evaluated in terms of a measure related to core damage frequency (CDF) or to changes in the measure (related to ΔCDF). The indicator combines operating experience for risk-significant initiating event classes with associated internal event CDF-based importance information. The indicator is able to appropriately combine frequent and infrequent initiating event class frequencies with different risk measures (Birnbaum importances). This indicator is termed the Baseline Risk Index for Initiating Events, or BRIIE. The main use of the BRIIE would be to combine individual initiating event class performance changes into an integrated, risk-informed indicator at the Initiating Events Cornerstone of Safety level. The BRIIE would solve several deficiencies in the present ITP: no systematic and defined method for determining whether individual initiating event class performance changes or adverse trends are risk significant, no systematic and defined method for integrating individual initiating event class performance changes into an overall risk result at the Cornerstone of Safety level, and untimely risk-informed industry trend results. Results of the BRIIE would be reported to the U.S. Congress.

Several different quantification methods were considered for evaluating the BRIIE. One method related to CDF is the following:

$$BRIIE = \sum_{i=1}^{m} \overline{B}_{i} \lambda_{ic}^{*}$$

where

$$\overline{B}_i$$
 = industry - average Birnbaum for initiating event i (1)

 $\lambda_{ic}^*$  = common industry current frequency for initiating event i

Another formulation, related to changes in CDF ( $\Delta$ CDF), is given by the following equation:

$$BRIIE = \sum_{i=1}^{m} \overline{B}_{i}(\lambda_{ic}^{*} - \lambda_{ib}),$$

where

 $\overline{B}_i$  = industry - average Birnbaum for initiating event i

(2)

 $\lambda_{ic}^*$  = common industry current frequency for initiating event i

 $\lambda_{ib}$  = baseline frequency for initiating event i

BWRs and PWRs have different core damage frequencies, which depend to some extent on different initiating event types. The risk weights for various initiating events are also different for the two types of reactors. Therefore, BRIIE results are proposed for each reactor type. However, the two BRIIE results could be combined into a single index, if desired.

The BRIIE formulations in Equations 1 and 2 use industry-average (or PWR- or BWR-average) Birnbaum importance measures and combine the industry-wide data to generate the "common industry current frequency" for each initiating event type. Alternative formulations are possible using plant-specific Birnbaum importances and plant-specific initiating event data and then summing the individual plant results to obtain an industry result. Results using all of the various calculation methods indicated that the proposed formulations in Equations 1 and 2 provide the most BRIIE sensitivity.

BRIIE results, although representing industry-wide results, are presented as average results per plant. This is done because NRC and stakeholders are more familiar with results per plant than with integrated industry-wide impacts. If the PWR BRIIE result for a future year is calculated to be 1.0E-6/year (per PWR), then the PWR-wide impact is actually (1.0E-6/year/PWR)(69 PWRs) = 6.9E-5/year. Similarly, if the BWR BRIIE is 1.0E-6/year (per BWR), then the BWR-wide impact is actually (1.0E-6/year/BWR)(34 BWRs) = 3.4E-5/year. These industry-wide impacts should be kept in mind when establishing reporting thresholds for the BRIIE.

Simulations of expected future performance of the PWR and BWR BRIIEs were performed to understand the nature of the distribution and to obtain 95% and 99% prediction limits. Reporting thresholds for the two BRIIEs should be established considering the following information:

- (1) Uncertainty in the BRIIEs and the 95% and 99% prediction limits from simulations
- (2) Distribution of the Birnbaum importance measures for each initiating event class and understanding of the groups of plants that have large values for each class
- (3) Major contributors (i.e., dominant initiating event classes) to the BRIIEs
- (4) Sensitivity of BRIIEs to initiating event classes, especially those with lower frequencies
- (5) Other factors, such as the NRC safety goal policy and Regulatory Guide 1.174

An expert panel would be established to propose BRIIE threshold values that satisfy policy and operational needs and objectives.

### 3 BRIIE Historical Performance and Sensitivity

Historical performance of the BRIIE ( $\Delta$ CDF basis) is shown in Figure A2-3 for FY 1997 through FY 2002. For all 6 years, the PWR BRIIE dominates the BWR BRIIE in terms of variance from a baseline  $\Delta$ CDF of 0.0. This shows why separate BRIIEs are proposed for PWRs and BWRs. For FY 1999, the PWR BRIIE peak of approximately 1.1E-5/year (per plant) is driven by two occurrences of a loss of DC bus. This illustrates the sensitivity of the BRIIE to relatively infrequent but risk-important initiating event types.

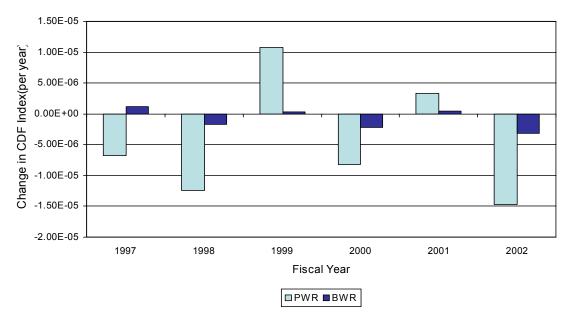


Figure A2-3 PWR and BWR BRIIE historical performance

To further investigate the sensitivity of the BRIIE to changes in frequency of individual initiating event types, results were calculated assuming all initiating event types are occurring at baseline frequency except for one, which is occurring at the Tier 1 prediction limit (95% or 99%). Sensitivity studies show the following. The PWR BRIIE is most sensitive to the small loss-of-coolant accident (LOCA) and loss of DC bus initiator types. Loss of offsite power, steam generator tube rupture, and stuck-open safety/relief valve initiator types also can affect the PWR BRIIE. Sensitivity results for the BWR BRIIE are different, with the loss of offsite power initiator class significantly affecting the BRIIE. To a lessor degree, loss of DC bus and stuck-open safety/relief valve initiator classes can affect BWR BRIIE results.

#### 4 Potential Responses to Tier 1 and Tier 2 Results

In this section we present two examples to show how the ITP might treat initiating event performance changes. For the first example, suppose we observe four events in 1 year that are classified as small/very small break LOCAs. Each event occurred in a separate plant. This initiating event is very rare. The 95% prediction limit is three events, and the 99% prediction

limit is four events. We have exceeded the 95% prediction limit and hit the 99% prediction limit. Because the number of actual events exceeds the prediction limit, this initiating event is a candidate for further investigation.

Because small LOCAs do not occur very often, NRC would probably look at each event in more detail after it occurred. Thus, NRC would have inspectors and staff reviewing each event. The ITP would look at these events to see if there were similarities among the events and to provide any lessons learned from this evaluation. These lessons would be communicated to the industry via some type of generic communication. Further regulatory action would probably not be necessary since the NRC investigated each event in detail.

Although BRIIE calculations have not been performed for this hypothetical case, the sensitivity study results (assuming the other initiating event types are at baseline performance) indicate that the PWR BRIIE would be approximately 9E-5/year (per PWR). This is significantly above the prediction limits of 2.2E-5/year (95%) and 3.5E-5/year (99%). However, an expert panel will decide what the actual thresholds for reporting to Congress will be. If the threshold were chosen to be the 99% prediction limit, then the report to Congress would identify the Initiating Events Cornerstone of Safety as a risk-significant departure from expected baseline performance and safety.

As another example, suppose that we see a marked increase in the number of general transients at a certain reactor type (PWR or BWR). We observe 74 general transients for the year. This exceeds both the 95% and 99% prediction limits, which are 61 and 67 respectively at the Tier 1 level. However, no unit has exceeded the white/green ROP threshold for scrams. The ITP investigates this situation and finds that the majority of the scrams occurred at plants of a specific reactor type. Further investigation reveals that a given device has been the cause of the majority of the general transients. This information could be communicated to industry via some type of generic communication.

In terms of reporting to Congress, at the Tier 2 level the BRIIE would probably indicate that this increase in general transients is not risk significant and would not exceed the threshold.